The Misallocation Costs of Bid Rigging: Evidence from Montreal Asphalt Procurement Auctions

Farhang Shamsoddin*

September 18, 2026

Abstract

This paper examines the misallocation costs of collusion in public procurement auctions using data from the Montreal asphalt cartel of 2007–2009. I estimate firm-specific cost distributions nonparametrically from the post-cartel period and simulate competitive counterfactual outcomes for each cartel-period auction. First, I find that the cartel inflated average procurement prices by 24 percent. Second, the inefficient allocation of contracts in the cartel period increased total production costs by 14.1 percent. Third, decomposing the price overcharge, 58.4 percent is attributable to misallocation of contracts toward higher-cost firms and the remaining 41.6 percent to higher collusive markups. These findings suggest that in markets with substantial dispersion in firm productivity, inefficient allocation may be the primary channel through which bid-rigging harms public buyers.

*Rotman School of Management, University of Toronto.

1 Introduction

Public procurement constitutes one of the largest single categories of economic activity in the modern economy. Governments around the world spend approximately 12% of global GDP purchasing goods, works, and services from the private sector, and in OECD member countries this share reaches 13% (World Bank, 2019; OECD, 2023). By recent estimates, the annual global value of public procurement exceeds $13 trillion (Open Contracting Partnership, 2020). Given this scale, even modest inefficiencies in how contracts are awarded translate into enormous economic losses. Competitive tendering, in which firms submit sealed bids and the contract is awarded to the most competitive offer, is the legally prescribed and most widely used mechanism for awarding such contracts (OECD, 2025). Whether these procurement auctions achieve their intended goal of efficiency is therefore a question of first-order economic importance.

A central threat to the efficiency of procurement auctions is collusion among bidding firms. When firms form a cartel, genuine competition is replaced by coordinated contract allocation, allowing cartel members to extract rents at the expense of the public buyer. Bid rigging is recognized by the OECD as one of the most harmful forms of anticompetitive conduct precisely because it targets government spending and undermines the public interest (OECD, 2025). A large meta-analytic literature documents the extent and severity of such conduct: Connor and Bolotova (2006) survey over 800 documented cartel episodes and report a mean overcharge of 29% and a median of approximately 20%, with procurement cartels frequently at the higher end of this range. The construction sector, which is the industry studied in this paper, is identified as particularly susceptible to bid rigging because of high entry barriers, large and predictable contract volumes, and a

homogeneous product that facilitates price coordination (OECD, 2025).

The most direct harm from procurement cartels is the overcharge, that is, the gap between the price paid by the government and the price that would have prevailed under competition. When firms collude rather than compete, the winning bid reflects a coordinated markup rather than the lowest cost of production. This drives up the public cost of procurement and may reduce the quantity and quality of public goods supplied below socially optimal levels. This paper quantifies the overcharge arising from the cartel in the Montreal asphalt paving industry. Using a structural auction model, I simulate competitive counterfactual outcomes for each cartel-period auction and find that average procurement prices were approximately 24% higher than under this simulated competitive benchmark. This estimate is consistent with the broader empirical literature on cartel overcharges, including the approximately 19% overcharge documented for the same industry by Clark et al. (2018) using reduced-form methods.

Beyond the overcharge, cartels impose a second and less-studied form of economic harm, which arises from the productive misallocation of output across firms. In a competitive market, contracts are won by the most efficient firms, that is, those with the lowest costs, ensuring that aggregate production costs are minimized. A cartel, by contrast, allocates contracts according to coordination rules that need not reflect underlying cost efficiency. Higher-cost firms may be awarded contracts they would never win under competition, while lower-cost firms are sidelined. The result is that the same quantity of output is produced at a higher aggregate cost than necessary, a form of productive inefficiency that is conceptually distinct from the overcharge and that compounds the total welfare losses from collusion.

The importance of resource misallocation across firms for aggregate economic performance is examined by Hsieh and Klenow (2009), who show that dispersion

in total factor productivity (TFP) across firms can account for large fractions of the TFP gap between developed and developing economies. In a frictionless competitive market, low-productivity firms are priced out by their more efficient rivals, resources flow to their highest-value uses, and productivity dispersion is limited. In the presence of distortions such as market power or collusion, high-cost firms remain active and productivity dispersion widens. Hsieh and Klenow (2009) estimate that reallocating inputs to their efficient uses could raise aggregate TFP by 30 to 60% in China and India relative to the United States.

A more direct approach to quantifying such misallocation is to compare the total cost of production under the distorted regime to what it would be under an efficient competitive benchmark. Asker et al. (2019) apply this approach to study the misallocation induced by OPEC in global oil extraction, finding large efficiency losses from cartel-driven deviations from least-cost production. Chaves et al. (2025) employ a related methodology to study misallocation in retail gasoline markets under collusion with differentiated products.

This paper quantifies the productive misallocation arising from the Montreal asphalt cartel in public procurement auctions and contributes to this literature along two dimensions. First, unlike Chaves et al. (2025), who study misallocation in a differentiated product market, my setting involves a homogeneous good procured through first-price sealed-bid auctions. This allows me to apply the structural auction framework of Guerre et al. (2000), which permits nonparametric identification and estimation of firm-level cost distributions directly from observed bids, and to recover both the overcharge and the misallocation within a unified structural framework. Second, this paper studies these effects in the context of public procurement, a sector that, as noted above, accounts for a substantial share of economic activity across countries.

I use data on 616 procurement auctions across 19 Montreal boroughs covering 2007 to 2013, comprising three years of cartel operation and four years of competitive market conduct following the cartel's collapse. This two-period structure underlies my empirical approach. I use the competitive period to estimate firm-specific cost distributions nonparametrically, following Guerre et al. (2000) extended to asymmetric bidders, with participation modeled via a probit that conditions on the distance between each firm's plant and the relevant borough. I then apply these estimates to simulate competitive counterfactual outcomes for each cartel-period auction and compare equilibrium outcomes under the cartel to this benchmark.

I find that the cartel increased the total cost of producing asphalt by 14.1 percent relative to the competitive counterfactual. This cost increase is itself one component of the broader price overcharge paid by public buyers, which reflects two distinct channels. Under competition, the lowest-cost firm wins and prices at a competitive markup. Under the cartel, contracts may be awarded to higher-cost firms, who must price above their higher costs and face weaker competitive pressure on their markups. My framework allows me to decompose the total price overcharge into these two components by comparing each cartel winner's price and cost to those of the corresponding simulated competitive winner, isolating the portion of the price gap due to higher costs from the portion due to higher markups. I find that 58.4 percent of the overcharge is attributable to the misallocation of contracts toward higher-cost firms, while the remaining 41.6 percent reflects higher collusive markups. The dominant channel through which bid-rigging harmed public buyers in this market was therefore productive inefficiency rather than relaxed competition. These findings suggest that overcharge-based assessments of cartel harm may not fully capture the total welfare cost of collusion, as they abstract from the

identity of the winning firm. This consideration is more relevant in markets with substantial dispersion in firm productivity, where the misallocation channel can be a primary source of harm. Accounting for this channel may therefore be useful for competition authorities assessing damages in procurement markets.

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature. Section 3 provides the institutional background on the Montreal asphalt procurement industry and the cartel. Section 4 describes my data. Section 5 presents the structural model. Section 6 details the estimation strategy. Section 7 presents the results. Section 8 concludes.

2 Related Literature

This paper is related to several branches in the economics literature. The first is the literature on structural estimation of auction models. Paarsch (1992) and Laffont et al. (1995) first established that the distribution of bidder private values can be recovered from observed bid data through parametric structural models. Guerre et al. (2000) provide the seminal nonparametric foundations for first-price auctions under independent private values, showing that the latent cost distribution can be nonparametrically identified and estimated in two steps: recovering pseudo-costs from the observed bid distribution and applying kernel density methods to estimate the underlying cost distribution. Athey and Haile (2002) further generalized the identification analysis across a broad range of auction formats, systematically clarifying what can and cannot be identified from bid data alone. Allowing for asymmetry across bidders, and most directly related to this paper, Flambard and Perrigne (2006) estimate separate cost distributions for two distinct types of bidders in snow removal procurement auctions in Quebec by distinguishing firms

by their proximity to the contract location. They show that accounting for this asymmetry is essential for understanding bidding behavior and market outcomes. Building on this line of work, this paper estimates firm-specific cost distributions nonparametrically in order to capture heterogeneity in cost efficiency across suppliers. Although asphalt is a largely homogeneous and standardized product, my results suggest that there is cost heterogeneity across firms, and that this heterogeneity makes the misallocation arising from the cartel economically non-trivial.

Second, this paper is related to a large empirical literature that documents the price effects of collusion. Connor and Bolotova (2006) synthesize more than 800 cartel overcharge estimates spanning over a century across dozens of industries and jurisdictions, documenting a mean overcharge of 29% and a median around 20%. Boyer and Kotchoni (2015) revisit this evidence using econometric corrections for bias and selection, obtaining lower bias-corrected estimates of around 16%. Individual studies have also documented overcharges from bid rigging in specific settings, including public procurement (Clark et al., 2018), retail gasoline (Clark and Houde, 2014), and school milk markets (Porter and Zona, 1999; Pesendorfer, 2000). This paper contributes to this literature by providing a structurally estimated overcharge for the Montreal asphalt cartel, finding a price effect of 24% which is consistent with the range documented in the broader literature.

Third, this paper is most closely related to a smaller but growing literature that goes beyond overcharges to measure productive misallocation, which is the efficiency loss that arises when collusion causes contracts to be awarded to higher-cost suppliers rather than the least-cost firms. Asker et al. (2019) study productive misallocation in global oil extraction, comparing actual total extraction costs under OPEC's production quotas to those that would prevail under efficient allocation. Chaves et al. (2025) examine misallocation in differentiated product mar-

kets, studying how uniform pricing under collusion distorts the allocation of sales across retail gasoline stations. This paper examines misallocation in a homogeneous-product procurement setting, arising from collusion in the Montreal asphalt industry, where the relevant efficiency benchmark is the counterfactual competitive outcome. My results indicate that the average cost of production during the cartel period would have been 14.1% lower had contracts been awarded competitively.

Finally, this paper contributes to the literature on the Montreal asphalt industry. Clark et al. (2018) exploit the cartel's collapse as a quasi-natural experiment and estimate a price overcharge of 19% using a difference-in-differences design that compares winning bids in Montreal before and after the cartel's collapse, using the Quebec market as a control. They also document entry deterrence as a further effect of the cartel. Clark et al. (2025) use detailed bidding records to study the internal mechanisms through which the cartel coordinated behavior. This paper complements these studies by estimating the overcharge from a structural auction model and by quantifying the productive misallocation arising from the cartel in Montreal asphalt procurement auctions. My overcharge estimate is consistent with that of Clark et al. (2018), and I find that the cartel increased the total cost of producing asphalt demanded by Montreal boroughs by 24 percent.

3 Institutional Background

In this section, I first discuss asphalt procurement in Montreal, then turn to the structure and main characteristics of the cartel.

3.1 Asphalt Procurement in Montreal

Montreal is the second most populous city in Canada, with a population of approximately 2 million residents. The city is organized into 19 administrative boroughs, each responsible for the maintenance and expansion of its local road network. To meet their annual infrastructure needs, boroughs independently forecast their demand for asphalt and procure it through a formal competitive tendering process. Private firms are invited to submit sealed bids for each borough's requirements, where a bid consists of a unit price per metric ton for each asphalt type requested, multiplied by the projected quantity and inclusive shipping costs. The auction is a first-price sealed-bid format: the firm submitting the lowest total bid is awarded the contract and is obligated to fulfill delivery. Boroughs retain the right to reject any bid deemed irregular. In practice, however, this authority is almost never exercised: in my sample period, only a single such rejection is recorded, in 2012.

The procurement process covers 11 distinct asphalt types, each suited to particular road conditions and engineering purposes. Within a given borough, at most one auction is held per asphalt type in any given year. Firms may bid on any subset of borough-type combinations, and participation is unrestricted in the sense that no formal prequalification is required. Boroughs contract only for the asphalt material itself; road repaving is carried out by municipal crews rather than by the winning firm (Clark et al., 2018). Depending on the asphalt type, the winning firm is either responsible for shipping the material to the borough or the borough arranges for its own pickup at the firm's plant. This structure is what ties a firm's distance from a borough to its cost of serving that contract, a relationship my model incorporates directly.

3.2 The Montreal Asphalt Cartel

In October 2009, the Radio-Canada investigative program *Enquête* broadcast an episode exposing a broad pattern of collusion and corruption in Montreal's construction industry. The broadcast drew considerable public and political attention, prompting the launch of *Opération Marteau*, a dedicated police investigation into the aforementioned allegations. These efforts ultimately led to the formation of the Charbonneau Commission in October 2011, a formal public inquiry mandated to investigate collusion, corruption, and organized crime infiltration in the awarding of public construction contracts.

Testimony before the Commission established that, while looser forms of coordination had existed in the Montreal construction industry since the 1980s, the asphalt cartel in its organized form was constituted in 2000. It originated among four dominant firms active in and around Montreal and was subsequently extended to encompass all six firms then operating in the city. The founding agreement covered three dimensions of coordination: the allocation of production quantities across members, the division of geographic territory, and the coordination of bid prices for the asphalt supplied to municipalities.

The cartel operated through three principal mechanisms. First, contracts were allocated in advance through private meetings among firm representatives, with assignments based on each firm's production capacity and proximity to the relevant borough. The designated winner then assumed responsibility for coordinating the submission process across all participants. Second, to satisfy the formal requirement of competitive tendering, non-winning firms submitted artificially inflated complementary bids. Communications were conducted in coded language to avoid detection: arrangements were conveyed through references to golf out-

ings, where hole numbers and player counts encoded bid thresholds. Third, the cartel actively suppressed outside competition through entry deterrence. Municipal informants within the procurement administration alerted the cartel whenever a non-member firm requested contract documentation. Such firms were contacted and instructed to withdraw; those who refused faced escalating pressure, including persistent harassment, physical threats, and in some cases sabotage of equipment and materials. Corruption of city officials—through gifts, entertainment, and political donations—served as a structural enabler of these practices, providing the cartel with advance access to contract information and a reliable early-warning system against outside entrants.

The *Enquête* broadcast and the investigations that followed effectively ended coordinated behavior in the Montreal asphalt market. By 2010, collusion had visibly abated, and bidding patterns in the subsequent years are consistent with competitive market conduct. This discontinuity provides the empirical foundation for my analysis: I treat the pre-2010 period as the collusive regime and the years 2010–2013 as the competitive benchmark, and use the latter to recover the structural primitives of the market under competition.

4 Data

I use borough-level data on asphalt procurement auctions in the city of Montreal covering the period 2007–2013. The sample spans seven years, comprising three years of cartel operation (2007–2009) and four years of competitive market conduct (2010–2013). The dataset contains two main components. First, for each auction, I observe the full set of submitted bids, the identity of all participating firms, and the identity of the contract winner. Second, I observe the addresses of all participating

firms' asphalt plants, which I use to compute the distance between each firm and each borough. Specifically, for each firm-borough pair, I calculate the Haversine distance in kilometers between the plant location and the centroid of the borough.[1]

Table 1 reports summary statistics for the auction data, separately for the cartel and competitive periods. The average number of participants per auction rises from 2.60 to 3.85, while the average winning bid falls from 75.37 to 66.20 CAD per metric ton. These patterns are consistent with the breakdown of collusion: more firms freely compete in each auction and their competition drives prices down.

Table 1: Summary Statistics of Auction Data

	Cartel (2007–2009)	Competitive (2010–2013)	Full Sample (2007–2013)
Number of Auctions	215	401	616
Total Bids Submitted	560	1,543	2,103
Avg. Bidders per Auction	2.60	3.85	3.41
Average Bid	75.94	70.02	71.60
Average Winning Bid	75.37	66.20	69.40

Bids are in CAD per metric ton.

Table 2 describes firm-level participation over the full sample. Nine firms appear in the data, though their activity patterns differ considerably across the two periods. Notably, Firms 7, 8, and 9 are entirely absent from the cartel period and only begin participating from 2010 onward, suggesting that the deterrence mechanisms may have effectively suppressed their participation during the collusive regime.

Table 3 reports, for each firm, summary statistics on the distribution of distances from its closest plant to Montreal's 19 boroughs. Distance to the relevant borough is a natural determinant of a firm's participation decision, as greater distance implies higher delivery costs and therefore a lower likelihood of submitting

[1] In cases where a firm operates more than one plant, distance is defined as the distance from the closest plant to the borough centroid.

Table 2: Summary Statistics for Firm-level Participation (Full Sample, 2007–2013)

Firm	Bids Submitted	Participation Rate	Auctions Won	Win Rate
1	609	0.9886	178	0.29
2	182	0.2955	60	0.33
3	213	0.3458	17	0.08
4	336	0.5455	203	0.60
5	218	0.3523	37	0.17
6	203	0.3295	12	0.06
7	212	0.3442	68	0.32
8	126	0.2045	40	0.32
9	4	0.0065	1	0.25

Win rate is defined as auctions won divided by bids submitted.

a competitive bid. The data are consistent with this: firms located closer to a borough participate more frequently than those located farther away. This relationship is formalized in the probit model of Section 5, and the estimation results in Table 4 confirm that distance is a negative and statistically significant predictor of participation.

Table 3: Firm-Borough Distance Summary Statistics (Kilometers)

Firm	Number of Plants	Mean Distance	Min Distance	Max Distance
1	3	7.35	0.18	23.19
2	3	9.19	1.08	18.77
3	2	11.20	2.83	23.37
4	3	9.19	1.08	18.77
5	1	10.84	2.46	22.35
6	2	12.42	4.51	18.67
7	1	15.93	1.82	32.77
8	2	16.02	7.88	35.07
9	1	20.56	3.47	33.98

5 Model

I model competition in procurement auctions as an asymmetric first-price sealed-bid game. The model has two stages. In the first stage, firms simultaneously decide whether to enter a given auction. In the second stage, those that have entered simultaneously submit sealed bids, and the contract is awarded to the lowest bidder at its own submitted price. I first characterize equilibrium bidding conditional on the set of active participants and then describe how participation is determined.

5.1 First-Price Procurement Auction

Consider an auction with n risk-neutral firms. Firm i privately observes its own cost c_i, drawn independently from a firm-specific distribution $F_i(\cdot)$ with density $f_i(\cdot)$. Firm i chooses a bid b_i to maximize its expected profit

$$\mathbb{E}\big[(b_i - c_i) \cdot \Pr(b_i < b_{-i})\big].$$

Let $S_j(\cdot)$ denote the equilibrium bidding strategy of any rival j. Firm i's profit maximization problem is then

$$\max_{b_i} \ (b_i - c_i) \prod_{j \neq i} \big[1 - F_j\Big(S_j^{-1}(b_i)\Big)\big],$$

where the right-hand side product captures the probability that all rivals submit bids above b_i. Taking the first-order derivative with respect to b_i gives

$$\prod_{j \neq i} [1 - F_j(S_j^{-1}(b_i))] + (b_i - c_i) \sum_{j \neq i} \left[\prod_{k \neq i, k \neq j} \big(1 - F_k(S_k^{-1}(b_i))\big) \right] \cdot \frac{-f_j(S_j^{-1}(b_i))}{S_j'(S_j^{-1}(b_i))} = 0.$$

Dividing through and rearranging yields

$$(b_i - c_i) \sum_{j \neq i} \frac{f_j(S_j^{-1}(b_i))}{S_j'(S_j^{-1}(b_i))} \cdot \frac{1}{1 - F_j(S_j^{-1}(b_i))} = 1. \tag{1}$$

Equation (1) is a system of differential equations that characterize the equilibrium outcomes of the auction. The estimation strategy for equation (1) is discussed in Section 6.

5.2 Participation

I model the entry decision as a binary choice that depends solely on the geographic characteristics of the auction. Specifically, the distance between firm i's location and the borough in which auction a is located determines the probability with which firm i participates.

I model the participation probability of firm i in auction a using a probit specification. Let $Y_{ia} \in \{0, 1\}$ be the binary participation indicator and Y_{ia}^* be the corresponding latent variable:

$$Y_{ia}^* = \alpha_i + \gamma \cdot d_{ia} + \varepsilon_{ia},$$

where α_i is a firm fixed effect capturing time-invariant differences in firms' willingness to participate, d_{ia} is the distance between firm i and the borough of auction a, γ measures the effect of distance on the participation decision, and $\varepsilon_{ia} \sim \mathcal{N}(0, 1)$. Firm i participates in auction a if $Y_{ia}^* > 0$, giving the participation probability

$$\Pr(Y_{ia} = 1) = \Phi(\alpha_i + \gamma \cdot d_{ia}), \tag{2}$$

where Φ is the standard normal CDF. Section 6 discusses how firms' participation

decisions affect the estimation of cost distributions.

6 Estimation

The estimation proceeds in two steps, following the nonparametric approach of Guerre et al. (2000), extended to asymmetric bidders. In the first step, I estimate firm-specific bid distributions and participation probabilities using data from the non-cartel period. In the second step, I use the structural inversion of equation (1) to recover a pseudo-cost for each observed bid, and estimate firm-specific cost distributions from the resulting pseudo-cost sample.

6.1 Bid Distributions and Participation

Let $\mathcal{L}$ denote the set of auctions in the non-cartel period. For each firm i, I estimate the bid CDF $G_i(\cdot)$ and PDF $g_i(\cdot)$ nonparametrically using a Gaussian kernel estimator with Silverman's rule-of-thumb bandwidth. To mitigate boundary effects, bids below the 5th and above the 95th percentile of each firm's bid distribution are trimmed prior to estimation.

Participation probabilities are estimated by the probit model in equation (2), using the non-cartel period. The estimated coefficients yield an auction-specific participation probability for each firm–auction pair, where d_{ia} is the distance between firm i and the borough of auction a. These auction-specific probabilities enter the cost inversion step as discussed in the next sub-section.

6.2 Cost Recovery

I recover structural costs from observed bids by inverting the equilibrium bidding condition in equation (1). Rearranging the first-order condition, the cost implied by a bid b submitted by firm i can be written as

$$c_i = b_i - \frac{1}{\sum_{j \neq i} \frac{g_j(b_i)\,\phi_{aj}}{1 - G_j(b_i)}}, \tag{3}$$

where $G_j(\cdot)$ and $g_j(\cdot)$ are the bid CDF and PDF of firm j, and ϕ_{aj} is the probit-predicted participation probability of firm j in auction a. Equation (3) follows directly from the equilibrium condition (1): the markup term is the inverse of the hazard-rate-weighted sum of rivals' bid densities, and equals the equilibrium markup implied by the first-order condition of firm i's profit maximization problem. The participation probabilities ϕ_{aj} enter because a rival who does not participate imposes no competitive pressure; the sum therefore weights each rival's hazard rate by the probability that the rival does indeed participate.

In practice, I evaluate equation (3) at the kernel estimates $\hat{G}_j(\cdot)$ and $\hat{g}_j(\cdot)$ obtained in Section 6.1 and use the auction-specific probit probability in equation (2). For each observed bid b_i, this yields a pseudo-cost estimate $\hat{c}_i$, giving a firm-specific sample of pseudo-costs $\{\hat{c}_i\}$ for each firm i.

6.3 Cost Distributions

In the second step, firm-specific cost distributions $F_i(\cdot)$ are estimated nonparametrically from the pseudo-cost samples, again using a Gaussian kernel with Silverman bandwidth. The resulting estimates $\hat{F}_i(\cdot)$ and $\hat{f}_i(\cdot)$ serve two purposes: they

provide the empirical characterization of cost heterogeneity across firms, and they are the direct inputs to the counterfactual analysis discussed in Section 7.

To assess the precision of the estimated cost distributions, I construct 95% confidence intervals using an auction-clustered bootstrap with 200 replications. In each replication I resample auctions with replacement, re-estimate bid distributions on the bootstrap sample, re-invert equation (3) to obtain bootstrap pseudo-costs, and re-estimate the firm-specific cost distributions. Confidence bands on the KDE density plots and confidence intervals on mean costs and standard deviations are obtained from the 2.5th and 97.5th percentiles of the bootstrap distribution.

7 Results

This section presents the empirical results in four parts. Section 7.1 reports the model estimates and the firm-specific cost distributions estimated from the non-cartel period. Section 7.2 measures the bid inflation attributable to the cartel. Section 7.3 defines and quantifies the misallocation induced by collusion. Section 7.4 decomposes the total price overcharge into its misallocation and markup components.

7.1 Firm-Specific Cost Distributions

Table 4 reports the estimates of the participation model in equation (2), estimated using data from the competitive period 2010–2013. The distance coefficient is negative and statistically significant, confirming that firms are less likely to participate in auctions located farther from their plants. The firm fixed effects are broadly comparable in magnitude across firms, with the notable exception of Firm 1, whose

substantially larger fixed effect is consistent with its near-universal participation rate in the data.

Table 4: Estimation Results of the Participation Equation (2)

Variables	Participate
Distance	-0.168^{***}
	(0.00759)
Firm 1	5.119^{***}
	(0.507)
Firm 2	0.982^{***}
	(0.0913)
Firm 3	1.148^{***}
	(0.0888)
Firm 4	1.606^{***}
	(0.101)
Firm 5	1.564^{***}
	(0.106)
Firm 6	1.887^{***}
	(0.109)
Firm 7	2.776^{***}
	(0.146)
Firm 8	1.784^{***}
	(0.116)
Firm 9	-0.351
	(0.285)
Observations	3,609

Standard errors in parentheses.
$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 5 reports the nonparametric estimates of firm-specific mean costs and standard deviations. Firm 7 has the lowest mean cost at \$57.18 per tonne, while Firm 3 has the highest at \$73.50 per tonne, a gap of approximately 28 percent. Figure 1 plots all eight cost distributions on a common axis; Figure 2 shows them

individually with 95 percent pointwise bootstrap confidence bands.

Table 5: Nonparametric Estimates of Firm-Specific Mean Costs

Firm	Mean Cost	95% Confidence Interval	Std. Dev.
1	64.90	[64.44, 65.68]	5.45
2	63.55	[61.41, 65.23]	8.78
3	73.50	[72.10, 75.42]	7.29
4	59.82	[58.99, 62.07]	10.36
5	67.94	[66.36, 68.95]	8.34
6	68.33	[67.06, 69.82]	8.46
7	57.18	[55.18, 60.23]	14.15
8	69.96	[67.25, 74.71]	16.14

Costs are in CAD per metric ton. Bootstrap confidence intervals based on 200 auction-clustered replications.

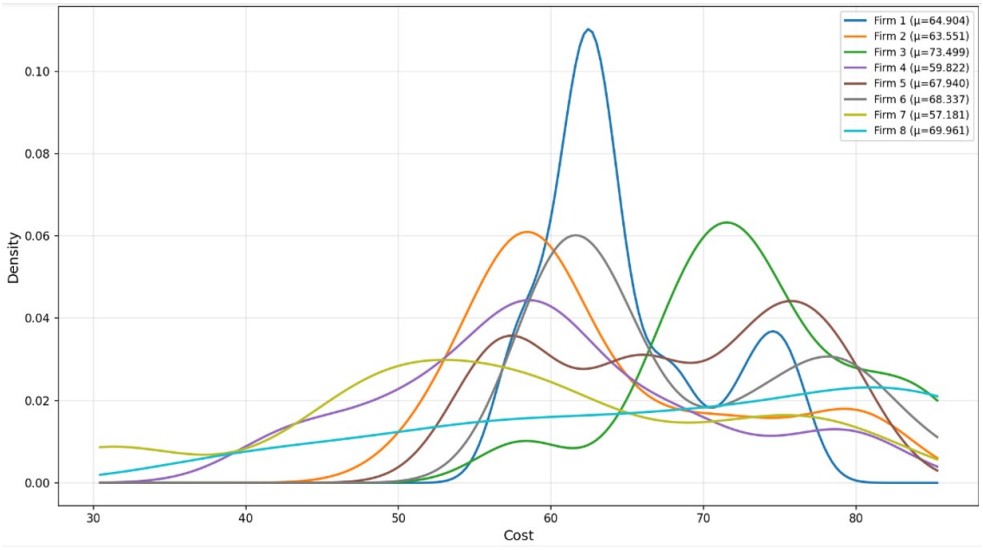


Figure 1: Firm-Specific Cost Distributions

The distributions are largely distinct across firms, with limited overlap in several cases. Pairwise Kolmogorov–Smirnov tests reject the null hypothesis of identical distributions for all 28 firm pairs at the 1 percent level, confirming that cost heterogeneity is a robust feature of the data rather than an artifact of estimation. This heterogeneity is the main force that makes the allocation question non-trivial:

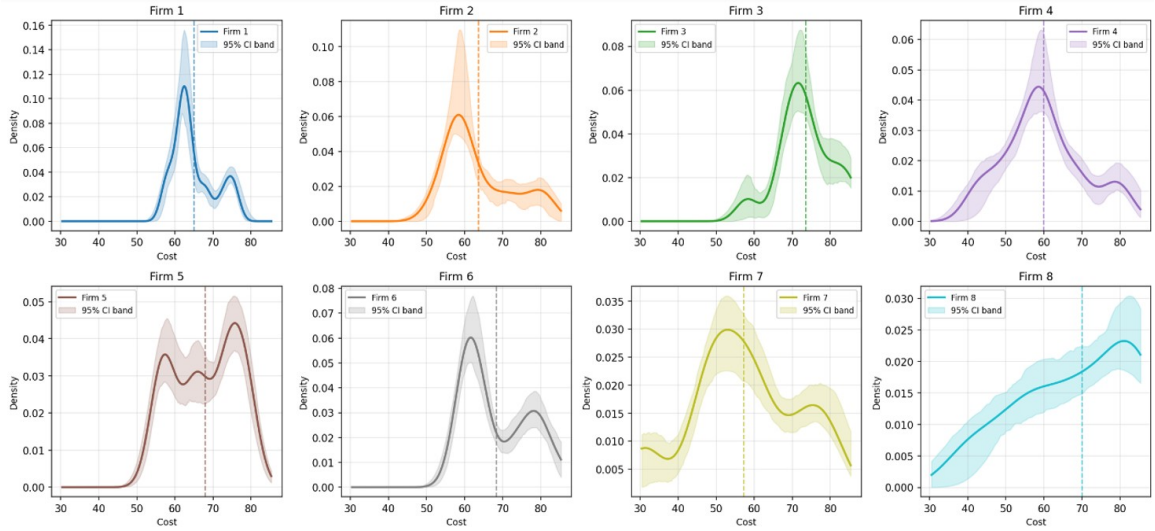


Figure 2: Firm-Specific Cost Distributions with 95% Confidence Interval Bands

when firms differ substantially in their production costs, who wins an auction has direct implications for productive efficiency.

7.2 Counterfactual Competitive Outcomes and Bid Inflation

To assess what auction outcomes would have looked like absent collusion, I simulate competitive procurement for each of the 215 cartel-period auctions. For each auction, firm-specific costs are drawn from the estimated distributions of Section 7.1, mapped through the equilibrium bidding functions, and the firm submitting the lowest bid is designated the competitive winner. Participation in each simulated auction is governed by auction-specific probit-predicted probabilities, preserving the geographic structure of entry rather than imposing uniform participation. Each auction is simulated 1,000 times and results are averaged.

The mean winning bid under the cartel was $75.37 per tonne, compared to a mean simulated competitive winning bid of $60.44 per tonne. This implies a price overcharge of 24.7 percent. This estimate is broadly consistent with the existing

literature. Clark et al. (2018), studying the same market using a difference-in-differences approach, find a price increase of around 20 percent. More broadly, Connor and Bolotova (2006), surveying overcharge estimates across a wide range of cartels, report a mean of 29 percent and a median of 20 percent, within which my estimate falls comfortably.

7.3 Misallocation

Beyond inflating prices, collusion may direct contracts toward higher-cost firms rather than those best positioned to execute them efficiently. I measure misallocation at the auction level as the difference between the mean cost of the cartel winner and the mean cost of the simulated competitive winner. A positive value indicates that the cartel's allocation rule assigned the contract to a firm with higher production costs than would have prevailed under competition.

My measure implicitly assumes that the cartel's allocation rule is independent of each firm's realized cost draw for a given auction. This is a reasonable working assumption given the evidence of systematic bid rotation in the cartel period, though I acknowledge it as a limitation.

The mean auction-level misallocation is \$8.77 per tonne, representing 14.1 percent of the cartel winner's mean cost. Positive misallocation is detected in 98.1 percent of cartel-period auctions, indicating that the distortion was systematic rather than incidental. Figure 3 plots the distribution of auction-level misallocation across all 215 auctions. The distribution is concentrated well to the right of zero, with a long right tail reflecting auctions in which particularly high-cost firms received the contract.

In a small number of auctions, measured misallocation is negative. This arises

when the cartel assigns the contract to a low-cost firm while the simulated competitive winner is not the lowest-cost firm, an outcome that is possible in asymmetric first-price auctions where differential bid shading means the lowest-cost firm does not always submit the winning bid. These cases are rare and do not affect the overall finding that misallocation was systematic.

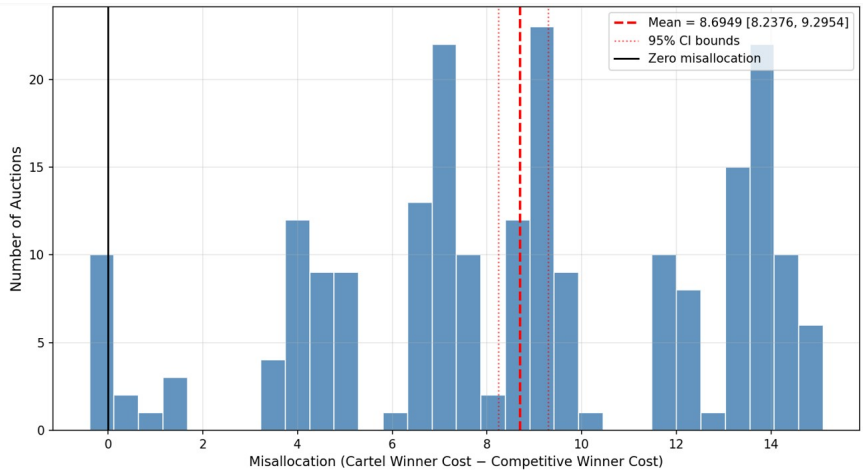


Figure 3: Distribution of Cost Misallocation Due to the Cartel

Finally, under the simulated competitive equilibrium, the lowest-cost firm would win 95.7 percent of auctions. Although in an asymmetric first-price auction the lowest-cost firm is not guaranteed to win—since firms shade their bids differently—the bidding advantage of lower-cost firms is sufficiently strong in my setting that the competitive equilibrium nearly replicates the efficient allocation.

7.4 Decomposing the Price Overcharge

The total price gap between the cartel period and the competitive counterfactual of Section 7.2 reflects two distinct channels. To see this, I rewrite the price gap as

$$p^{\text{cartel}} - p^{\text{comp}} = \underbrace{\left(p^{\text{cartel}} - c^{\text{cartel}}\right) - \left(p^{\text{comp}} - c^{\text{comp}}\right)}_{\text{markup channel}} + \underbrace{\left(c^{\text{cartel}} - c^{\text{comp}}\right)}_{\text{misallocation channel}}.$$

The first bracketed term captures the difference in markups between the two scenarios. Under the cartel, firms face weaker competitive pressure and are therefore able to charge higher markups above their own costs. The second term reflects the misallocation effect: since the cartel's allocation rule directs contracts to higher-cost firms, winning firms must charge higher prices simply to cover their higher production costs.

The mean total price gap is \$14.93 per tonne. Of this, \$8.69 per tonne is attributable to misallocation, while the remaining \$6.24 per tonne reflects the higher markups charged by cartel winners relative to what a competitive winner would have charged in equilibrium. The dominant source of the price overcharge is therefore the misallocation of contracts rather than the charging of higher collusive markups.

This suggests that the welfare cost of collusion through misallocation is increasing in the dispersion of production costs across firms: the more heterogeneous firms are, the larger the efficiency loss from directing contracts away from low-cost producers due to collusive conduct. In markets characterized by substantial productivity differences, the misallocation channel may therefore be a primary mechanism through which bid-rigging harms buyers, a consideration that antitrust policy should account for when assessing the welfare costs of collusion.

8 Conclusion

This paper quantifies the welfare costs of collusion in public procurement auctions using data from the Montreal asphalt cartel, which operated between 2007 and 2009. I estimate firm-specific cost distributions nonparametrically from the post-cartel competitive period and simulate competitive counterfactual outcomes

for each cartel-period auction within an asymmetric first-price auction framework with endogenous participation.

Three results emerge. First, the cartel inflated average winning bids by 24.7 percent relative to the competitive counterfactual, consistent with the broader cartel overcharge literature. Second, the cartel induced productive misallocation; the inefficient allocation of contracts increased total production costs by 14.1 percent relative to the competitive benchmark. Third, decomposing the total price overcharge reveals that 58.4 percent is attributable to the misallocation of contracts toward higher-cost firms, while the remaining 41.6 percent reflects the higher markups charged under collusion. The dominant harm from bid-rigging in this market is therefore through productive inefficiency rather than through relaxed competition.

These findings suggest that productivity dispersion across firms is a quantitatively important determinant of the welfare costs of collusion. In markets where firms differ substantially in their production costs, the misallocation of contracts away from efficient producers can constitute the dominant source of harm from bid-rigging, outweighing the losses arising from higher collusive markups. Standard overcharge-based assessments of cartel harm, which abstract from the identity of the winning firm, will therefore understate total welfare losses in such settings. More generally, these results suggest that productivity dispersion across firms amplifies the welfare costs of collusion: the more heterogeneous firms are, the greater the efficiency loss from directing contracts away from low-cost producers.

References

Asker, J., Collard-Wexler, A., and De Loecker, J. (2019). (mis)allocation, market power, and global oil extraction. *American Economic Review*, 109(4):1568–1615.

Athey, S. and Haile, P. A. (2002). Identification of standard auction models. *Econometrica*, 70(6):2107–2140.

Boyer, M. and Kotchoni, R. (2015). How much do cartels overcharge? *Review of Industrial Organization*, 47(2):119–153.

Chaves, I., Clark, R., Duarte, D., and Houde, J.-F. (2025). Collusion and misallocation in retail gasoline markets. Working paper.

Clark, R., Coviello, D., and De Leverano, A. (2025). Internal mechanisms of cartel coordination. Working paper.

Clark, R., Coviello, D., Gauthier, J.-F., and Shneyerov, A. (2018). Bid rigging and entry deterrence in public procurement: Evidence from an investigation into collusion and corruption in quebec. *Journal of Law, Economics, and Organization*, 34(3):301–363.

Clark, R. and Houde, J.-F. (2014). The effect of explicit communication on pricing: Evidence from the collapse of a gasoline cartel. *Journal of Industrial Economics*, 62(2):191–228.

Connor, J. M. and Bolotova, Y. (2006). Cartel overcharges: Survey and meta-analysis. *International Journal of Industrial Organization*, 24(6):1109–1137.

Flambard, V. and Perrigne, I. (2006). Asymmetry in procurement auctions: Evidence from snow removal contracts. *Economic Journal*, 116(514):1014–1036.

Guerre, E., Perrigne, I., and Vuong, Q. (2000). Optimal nonparametric estimation of first-price auctions. *Econometrica*, 68(3):525–574.

Hsieh, C.-T. and Klenow, P. J. (2009). Misallocation and manufacturing TFP in China and India. *Quarterly Journal of Economics*, 124(4):1403–1448.

Laffont, J.-J., Ossard, H., and Vuong, Q. (1995). Econometrics of first-price auctions. *Econometrica*, 63(4):953–980.

OECD (2023). Government at a glance 2023. Technical report, OECD Publishing.

OECD (2025). Guidelines for fighting bid rigging in public procurement. Technical report, OECD Publishing.

Open Contracting Partnership (2020). Open contracting data standard. Technical report, Open Contracting Partnership.

Paarsch, H. J. (1992). Deciding between the common and private value paradigms in empirical models of auctions. *Journal of Econometrics*, 51(1–2):191–215.

Pesendorfer, M. (2000). A study of collusion in first-price auctions. *Review of Economic Studies*, 67(3):381–411.

Porter, R. H. and Zona, J. D. (1999). Ohio school milk markets: An analysis of bidding. *RAND Journal of Economics*, 30(2):263–288.

World Bank (2019). World development report 2019. Technical report, World Bank.